A Pavement Preservation Strategy

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ABSTRACT

An effective pavement management system requires a comprehensive pavement preservation strategy (PPS). Wisconsin's PPS is guided by a philosophy whose goal is to optimize pavement performance in a manner which provides the highest quality service to the customer per unit of expenditure. The PPS is customer oriented and views "service" in terms of user comfort, convenience and safety. The strategy is broad-scoped and considers all pavement management activities from "do nothing" to "reconstruction".

Wisconsin's PPS has program values that are based upon solid research which has been field verified. The treatment alternatives for pavement problems address the causes not the symptoms of a particular problem -- thus the root cause of the problem is addressed and funds are not used to treat merely a symptom. Accordingly, the PPS is termed a cause-based strategy rather than a schedule -based (applying treatments on a predetermined schedule), or a worst-first based strategy (treating the worst pavements first).

The PPS follows a logical progresses trough a series of evaluations to convert a set of from raw, field collected data (ride and distress), ultimately, to a set of recommended actions. The process moves from raw data to an evaluation of the level of the distress. Combinations of distress levels are used to identify specific pavement problems. In turn these pavement problems are evaluated as a family, to generate appropriate solutions.

INTRODUCTION

The Wisconsin Department of Transportation (WisDOT) established a Pavement Policy Committee in 1992. The ongoing goal of this committee is to provide pavements which are cost effective, maximize service life with minimal maintenance and meet the overall expectations of the traveling public with respect to comfort, convenience and safety. One of the principle issues this committee originally addressed was the establishment of a comprehensive Maintenance and Rehabilitation Strategy, which grew into Wisconsin's Pavement Preservation Strategy (PPS), the subject of this report.

Pavement preservation can be defined as follows (fashioned after the American Association of State Highway and Transportation Official's definition):

"Pavement preservation is the planned strategy of cost-effective pavement treatments to an existing roadway to extend the life or improve the serviceability of the pavement. It is a program strategy intended to arrest deterioration, retard progressive failure and improve the functional or structural condition of the pavement. It is a strategy for individual pavements and for optimizing the performance for a pavement network".

BACKGROUND

WisDOT has generally allowed each district office to decide what pavement preservation treatment to apply and when to apply it. The districts used the first computerized version of Wisconsin's Pavement Management System (PMS) in varying degrees as a tool in making treatment decisions for planning and programming purposes. However, by the early 1990's, the original PMS was outdated and not viewed with confidence. Thus, the majority of decisions continued to be made independently, using engineering judgment and previous experience as the guiding factors (1). All too often, these factors amounted to doing a certain thing because "that is what we have always done". It also resulted in a lack of uniformity from district to district as well as in inconsistency over time.

There were four major problems that caused a lack of confidence in the early PMS:

1. Research had not addressed many of the Pavement Preservation issues.
2. Technology advances in road building had not been properly incorporated.
3. The PMS was viewed as a "black box solution", *i.e.*, it derived a preferred treatment but few understood the logic leading to that treatment, and it derived only one solution to a problem rather than giving district personnel decision support information.
4. Pavement deterioration models had not yet been incorporated. Since actual construction can lag the PMS planning process by 6 years, by the time construction took place the continued deterioration of the pavement resulted in poor quantity estimates for repair and the choice of treatments was often wrong for the condition at that time.

These problems were all addressed in a recent reevaluation and redevelopment of WisDOT's PMS based on the following:

1. Research over the last 10 years has concentrated on providing insight into whether or not a treatment enhances pavement performance (improves ride, reduces maintenance, extends life, reduces distress, etc.). Then, if there was enhanced pavement performance the treatment was evaluated to determine if it was a cost-effective enhancement. Finally, if the enhancement was cost effective, the best materials or techniques were evaluated.
2. Technology in road building has advanced rapidly in the last couple of decades. The results of these advancements were sought, considered, and appropriately incorporated in the PMS.
3. Wisconsin's PMS was carefully reviewed and revised using the Pavement Preservation Strategy presented here. Not only were the treatments revised but the resulting output provides more for decision support information than just a single solution. For each section of road, the evaluation contains information on all treatments. Computerized evaluation routines summarize the acceptability and appropriateness of these treatments. The evaluation concludes by determining which solution is the "lowest cost", "best value" and "longest life" alternative.

4. Pavement deterioration models have now been developed and incorporated in the PMS.

BENEFITS

The benefits that the DOT expects from the Pavement Preservation Strategy presented herein are:

1. Better quality transportation.
2. Longer pavement service lives.
3. Reduced customer inconvenience and delays.
4. Reduced life cycle costs.
5. Increased customer satisfaction.
6. Improved decision making for transportation planning and programming.
7. Increased uniformity and consistency in the design and construction of transportation facilities.
8. More efficient use of transportation funds.
9. Logical, objective, and defensible transportation policies based on research and proven performance.

PAVEMENT PRESERVATION PHILOSOPHY

A pavement preservation strategy has to have a philosophy to guide the conceptual aspects, to determine its scope of influence, and to established program values. Wisconsin's strategy is based upon the following philosophy.

While the PPP may not appear as a traditional pavement preservation philosophy it does treat problems at the correct time in order to use money and resources wisely. It is the pavement preservation philosophy under which WisDOT currently operates.

Concepts

The Pavement Preservation Philosophy is based upon infrastructure optimization. The goal is to provide the highest quality service possible to the customer per unit of expenditure.

Wisconsin's PPP is customer oriented. Each maintenance or rehabilitation venture must address the issues of primary importance to the customer:

1. How does it effect COMFORT: ride, noise, aesthetics...the customer's senses.
2. How does it effect CONVENIENCE: delays, time....the value of the customer's time
3. How does it effect SAFETY: the customer's life.
4. How does it effect COSTS: the customer's pocket book.

Scope

Wisconsin's PPS is as broad in scope as possible. It is guided by a philosophy of inclusiveness which covers all pavement management activities for the life of a pavement, from the "do nothing" alternative to the reconstruction alternative. The PPS is broad in the scope of pavements involved, thus each pavement section on the State Trunk Highway System is examined to determine the appropriate strategy for preservation, be it do nothing, reactive/routine maintenance, preventative maintenance, thin overlay, thick overlay, rehabilitation, reconditioning, or reconstruction. Thus, it is a comprehensive strategy that recognizes that the various aspects of programming and system wide performance which must all be considered in a PPS.

Program Values

1. Wisconsin's PPS is research based. Each maintenance and rehabilitation treatment was subjected to this series of questions, and in this order.
   a. Does the proposed treatment in any way enhance pavement performance (see "Concepts", item B above). If not, it was not used. If so, then item 1b (below) was considered. This item is very important and is a program value very often overlooked in research. Research evaluations must not

concentrate on the treatment's life or performance but on the treatment's effect on the pavement's life and performance.

   b. Is the proposed treatment cost - beneficial. If not it was not used. If so, then item 1c (below) was considered.
   c. What is the best material, technique, methodology, timing, level of distress, etc., for optimum performance.

2. WisDOT's PPS is experience verified. Research results, new technologies, and existing treatments were carefully scrutinized by experts with recognized field and pavement performance experience.
3. WisDOT's PPS treats cause(s) not symptoms. The PPS is designed to evaluate symptoms of distress (cracking, rutting, ride, etc.) and to make a diagnosis of the cause(s) of those symptoms. The cause(s) is addressed in the treatment strategies (the treatments are thus solutions) so the root of the problems is addressed and so that symptoms are not treated but the actual problems are. This helps assure treatment strategies that are cost effective and that are based upon customer values.

   The PPS proceeds thusly:

   a. Individual distress types are rated for severity and extent for nominal one-mile segments on the entire state highway system. These distress types are (SYMPTOMS) of a problem.
   b. Ride levels are measured on the same segments (SYMPTOMS).
   c. Pavement problems are determined based upon the ride and individual distress ratings. These problems are the (CAUSE) of the symptoms.
   d. Treatment strategies determine the proper "fix for each problem. These strategies are the SOLUTION to the cause.

4. WisDOT's PPS is timely, not time based. The PMS is based upon the correct treatment of the existing pavement conditions --A CAUSE-BASED PMS. It is not a schedule-based PMS, e.g., for an asphalt pavement program to have a pre-determined program to seal cracks at year X and to apply a seal coat at year Y is a schedule-based PMS. A schedule-based PMS has the advantages of ease of budgeting and programming, but it often results in poor treatment choices for existing problems. WisDOT believes a CAUSE-BASED PMS provides the best quality service to the public per unit of expenditure.
5. WisDOT's PPS is appropriate, not automatic. The PMS is geared toward identifying and treating problems as and before they become severe. Systems where pavements are allowed to deteriorate to termination and then the worst pavements are treated first (a worst-first PMS) are not believed to be cost effective.
6. A complete set of treatment alternatives are evaluated. A number of alternative treatments for the existing pavement problems are generated. These treatments range from "do nothing" to simple maintenance procedures, to complex maintenance, to rehabilitation, to reconstruction. The final treatment selected is based upon highway functional classification, ability to treat all the pavement

problems, initial costs, life cycle costs, cost - benefit, age and expected life of the pavement.

7. The PPS employs pavement performance models. These models were derived from over a decade of pavement performance data collection. These models depict the rate of deterioration in ride and distress over time for each pavement type. They also indicate which individual distress types ultimately control the life/performance of each pavement type. Thus, performance models enabled sound decisions to be made on which distresses need immediate attention (routine or preventive maintenance) and where to focus research in order to get the best pay-back.

RESEARCH BASE

A mass of specifically targeted research in the last decade provides the foundation for Wisconsin's PPS. The research was carefully designed to address specific problems and potential treatments. Great care was taken to keep the research focused and to get practical, applicable results. A summary of this research appears in Table 1. TABLE 1. Summary of Applied Research

Item Researched	Findings
1. Continuously reinforced concrete pavements - delamination due to corrosion of steel. (2)	Preventive Maintenance (cathodic protection and corrosion inhibiting salts) are not cost-effective. The best rehab strategy is a 3 inch overlay before significant distress occurs.
2. Reflective Crack Control (3)	Polymers not cost-effective, stress absorbing membrane inter-layers are not cost-effective, fabrics are of some value for longitudinal cracks but not for transverse cracks.
3. PCC Joint Sealing (4)	Not cost-effective
4. AC Crack Sealing (5)	Cost-effective in some cases, especially in improving winter ride.
5. Seal Coating (6)	Can be cost-effective for surface raveling, not cost-effective for any full depth cracking problem, seal coats do not prevent further "drying out" of the mix (not cost-effective in preventing block cracking/aging).
6. Concrete Pavement Repair(7)	For jointed reinforced concrete, use full depth repairs at joints (partial depth away from joints in acceptable), full lane-width repairs required (no partial lane), repair and grind is cost-effective (but only when repairs are less than 10% of the surface area.
7. Rut Repair	Rut filling, micro-surfacing and milling are all potential treatments.
8. Fog Sealing	Not cost effective
9. AC over PCC (8)	Rubblizing, crack and seating, break and seating are being evaluated, some interim results guided PPS

	effort.
10. AC Recycling	Cold-in-place recycling can be cost-effective on lower volume roads, hot recycling of AC is general practice, PCC can be recycled as aggregate in new PCC.
11. Retrofit Edge Drains (9)	Retrofitting edge drains with an existing dense base is not cost-effective.
12. Tenting (raising of pavement at crack/joint during cold weather)(10)	Transverse inter-flow channels not cost-effective.
13. Premature PCC deterioration (NW Wisconsin problem -- secondary ettrivgite formation)(11)	No effective preventive maintenance found, most cost-effective rehab is a three inch overlay before the distress becomes severe.
14. Slab Jacking (12)	Not cost-effective for normal faulting situations (causes more distress and lowers ride), good for bridge approach slab problems.
15. Culverts (13)	Slip liners can be cost-effective and the process does not disrupt traffic.
16. Faulting	Dowels are required in all new pavements and repairs. Grinding of undowelled pavements is a necessity to restore ride but its life is not the expected 10-15 years, retrofit dowels are encouraged but not well researched in Wisconsin.
17. Overlays	Thin overlays are cost-effective for non-structural problems. Thick overlays required for structural problems.
18. D-Cracking	Concrete pavement repair and grinding is not cost-effective for moderate or worse cases of D-Cracking; overlays are cost-effective.
19. Alkali-Silica (or carbonate) Reaction	Rare in Wisconsin - normal maintenance and rehab scenarios apply.

Focused research concentrates on user comfort, convenience, safety, and costs (see Concepts section). Focused research makes a clear distinction between treatment performance and the treated pavement's performance (a concept often missed in research).

For example, suppose a seal coat were applied to a pavement. The evaluation of the effectiveness of the seal coat relates to the effect the seal coat has on the life and/or performance of the pavement itself. The effectiveness of a seal coat is NOT evaluated by studying the life of the seal coat itself. A seal coat may look good and perform well for 10 years but that is not the issue -- what the researcher must determine is the additional life or performance imparted to the pavement. If the pavement fails at year 15 without a seal coat and at age 15 with a seal coat, what value was the seal coat? If the pavement performance models show that seal coated pavements fail at 18 years then there is a benefit for seal coating. The next step would be to determine if the three extra years of life indicate a seal coat is cost-effective.

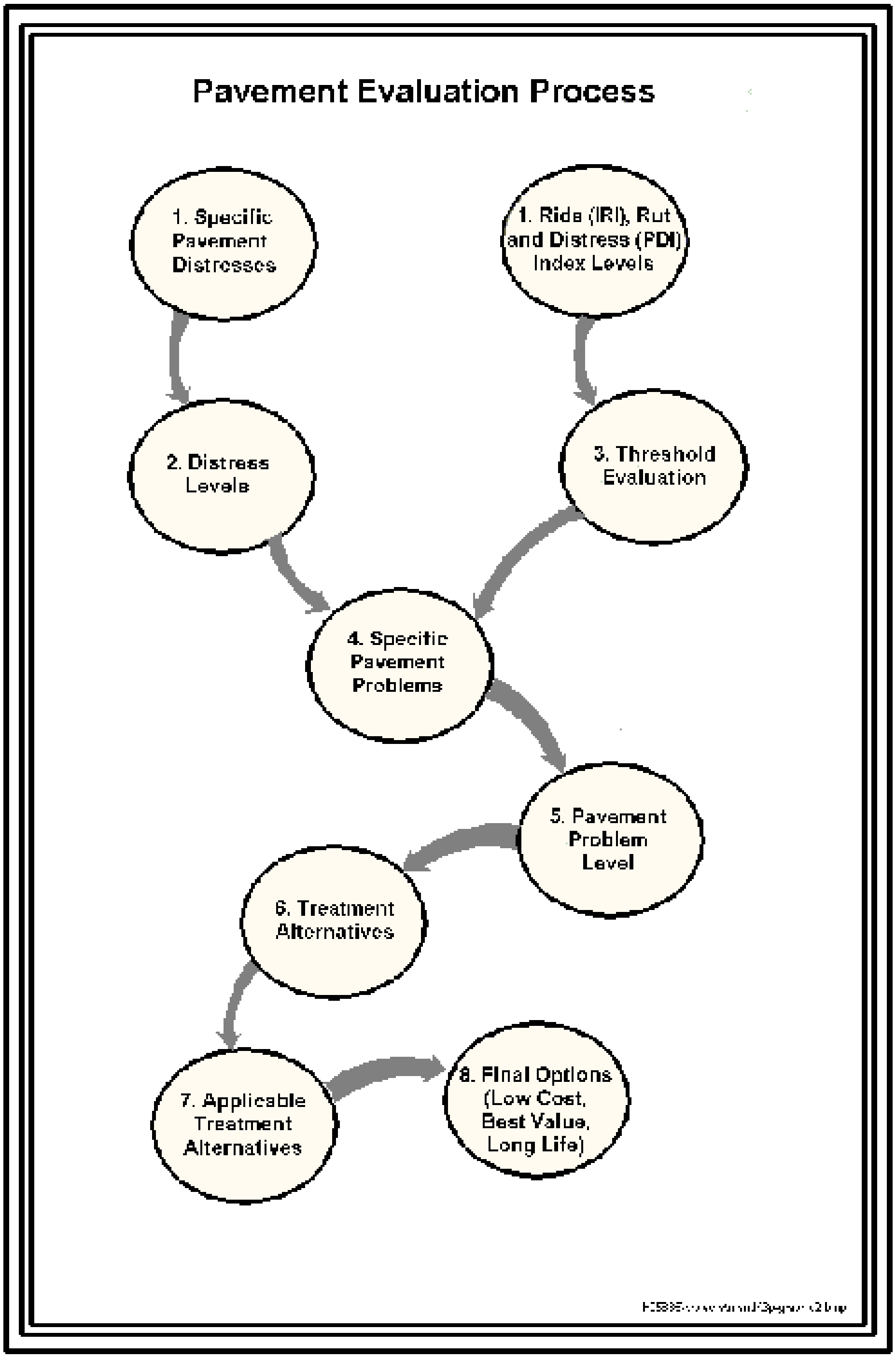
OVERVIEW

Prior to discussing the specifics of the Pavement Preservation Strategy a brief overview will be given. This overview will establish the goal and direction of the Strategy prior to presenting a detailed look at the PPS. Pure pavement management decisions in Wisconsin are guided primarily by three factors - distress, ride and rutting. These factors are considered in this Strategy.

The goal of this new Strategy is to determine a logical treatment to apply it to a pavement which is exhibiting a given set of deficiencies. By using this strategy, a more uniform and defensible expenditure of tax dollars will occur. The process underlying the new strategy is presented below. For each pavement section (nominal one-mile in length):

1. Determine the specific pavement distresses from field measurement. Measures are typically rated for severity and extent of the distress. Also, measure ride and rut levels.
2. Categorize each specific pavement distress into one distress level. Thus, each specific pavement distress is simplified into a form that qualitatively relates the impact of that distress to overall pavement performance. The levels are none, minor, moderate, and severe.
3. Determine if the section exceeds one or more distress, ride, or rut thresholds. Note that these thresholds vary with highway functional class.
4. If the section exceeds a threshold, the distress level data is evaluated to determine the specific pavement problem(s).
5. The specific pavement problem(s) are evaluated to determine the pavement problem level.
6. Use the pavement problem(s) levels to determine the treatment alternatives for each problem.
7. When multiple pavement problems exist in a pavement section, evaluate all problems to determine that section's proper treatment alternative(s).
8. When there are multiple treatment alternatives for a number of sections, determine the final options for a project length roadway.

These steps are illustrated in the graphic that follows:



This methodology is designed to address the actual pavement problem(s) not just to treat an individual symptom. Using a medical analogy, if one has a pain in the right side (symptom), it would be poor practice to treat the symptom with pain killer. Instead, a diagnosis is required to address the underlying cause of the problem. If the problem were an appendicitis, the appropriate treatment would certainly not be the use of a pain killer. In pavement engineering as well as in medicine, a proper diagnosis must be made to ensure treatment of the problem not relief of the symptom.

A real-world example can help relate the above medical analogy to the practice of pavement management. If a pavement has fatigue cracking (symptom), would a correct solution be to seal the cracks or to apply a seal coat? If the diagnosis of this symptom lead one to conclude that the pavement problem is one of insufficient structure for the imposed loading, then both crack sealing and seal coating only address (hide) the symptom but don't treat the problem. The problem is structural in nature and requires a treatment that addresses the lack of structure such as a thick overlay. Treating the symptom does nothing to alleviate the problem, and the fatigue cracking will soon reappear.

PAVEMENT EVALUATION PROCESS

Specific Pavement Distresses

In the early 80's, WisDOT began to survey pavement distress using visual observations of surface conditions. The state trunk system is broken into nominal one-mile sections, and a sample of each section is rated for distress. There are typically two measures made for each individual distress type -- severity and extent. Severity describes how serious the damage is on the pavement, while extent describes how much of the pavement section is affected by the problem.

There are a total of twelve specific pavement distresses indicators for Asphalt Concrete pavements (examples, transverse cracking, edge raveling). Portland Cement Concrete pavements have six specific pavement distresses (examples, slab breakup, faulting). There are four additional distresses surveyed for CRC pavements (examples, wide cracks, punchout).

These distresses and their associated ratings can be aggregated to calculate the Pavement Distress Index or PDI. The value of this index ranges from 0 to 100, where 0 represents no distress and 100 is something akin to rubble. PDI is an estimation of the relative structural integrity of a pavement exhibiting various levels of distress. Although used heavily in the planning and programming processes, PDI has limited use for determining project-specific engineering solutions. As indicated above, specific pavement distresses are the relevant factors for diagnosing problems and proposing solutions (treatments).

Distress Levels

After quantitatively measuring specific pavement distresses, they are assigned to one of four distress levels -- none, minor, moderate, or severe. Distress levels must be attributed to the pavement because a qualitative diagnosis is required from the quantitative data. Examples of this process are shown in Table 2.

TABLE 2. Pavement Distress Levels (examples, not a complete list)

FLEXIBLE PAVEMENT DISTRESSES

Flushing

Severity	
Insignificant	Moderate
Significant	Severe

Transverse Cracking

Severity (crack	Extent (avg. cracks per station)

characteristics)	1-5	6-10	11+
≤ 1/2" wide	Minor	Moderate	Moderate
> 1/2" wide	Moderate	Moderate	Severe
Dislodgement	Moderate	Severe	Severe

Longitudinal Cracking

Severity (crack	Extent (length in feet per station)			
characteristics)	1-100	101-200	201-300	> 300
≤ 1/2" wide	Minor	Minor	Moderate	Moderate
> 1/2" wide	Minor	Moderate	Severe	Severe
Dislodgement	Moderate	Severe	Severe	Severe

PORTLAND CEMENT CONCRETE PAVEMENTS

Transverse Faulting

Severity	Extent (avg. number of faulted joints per station)		
(faulting height)	<1	1-2	3 or more
<1/4"	None	Minor	Minor
1/4" - 1/2"	Minor	Moderate	Severe
> 1/2"	Moderate	Severe	Severe

Longitudinal Joint Distress

Severity	
Slight (1-48'/station)	Minor
Moderate (49-96'/station	Moderate
Severe (>96'/station)	Severe

Distressed Joints/Cracks

	Extent (avg. cracks per station)		
Severity	1 - 2	3 - 4	5 or more
Slight	Minor	Minor	Moderate
Moderate	Moderate	Severe	Severe
Severe	Severe	Severe	Severe

ALL PAVEMENTS

Ride

Ride Rating IRI *(PSI)*	Route Type		
IRI (PSI)	Principle Arterial	Minor Arterial	Collector
<2.50 *(>3.00)*	None	None	None
2.50 - 2.75 *(3.00-2.75)*	Minor	None	None
2.75 - 3.00 *(2.75-2.50)*	Moderate	Minor	None
3.00 - 3.50 *(2.50-2.00)*	Severe	Moderate	Minor
3.50 - 3.75 *(2.00-1.75)*	Severe	Severe	Moderate
>3.75 *(<1.75)*	Severe	Severe	Severe

Ride and Rut Index Levels

Another factor critical to evaluating pavement performance is ride. Where distress characteristics measure the structural integrity of a pavement, ride measures comfort provided to the users (drivers and passengers) of the roadway.

Ride is also used to assign a pavement problem level (none, minor, moderate and severe). The problem level varies by functional class of the roadway. Specific values are shown in Table 3.

TABLE 3. Pavement Thresholds

	Action Type					
	Should			Must		
Highway Classification	PSI	PDI	RUT	PSI	PDI	RUT
Interstate, Principle Arterial	2.75	65	0.35	2.25	85	0.6
Minor Arterial, Major Collectors	2.25	70	0.50	1.75	90	0.75
Minor Collectors, Local Roads	1.75	80	0.50	1.50	90	0.75

Threshold Evaluation

As part of the planning and programming process, the ratings for ride, distress (using the PDI value) and rutting are evaluated. The ratings for these three characteristics are measured on nominal one-mile sections of road. These ratings are then aggregated to evaluate "logical project lengths". The aggregated values are then compared to the thresholds shown in Table 3. The thresholds are broken down by highway type (functional class). They are further grouped by the levels where action is recommended (should level) and action is mandatory (must level). A treatment is suggested for any pavement section where one or more thresholds are met or exceeded. The assignment of specific treatments is discussed in the next section.

It should be noted that the analysis methods described above pertain to pavement problems only. Pavement issues are just one of many reasons for taking action on a given section of highway. In those cases where pavement condition is not an issue yet a project is envisioned, the specific problems outlined below can be used to help suggest a course of action.

Specific Pavement Problems

Distress, ride, and rut values all interact to define a specific pavement problem for the section of roadway being evaluated. The methodology for determining specific pavement problems is the diagnostic step that is critical to determining the correct solution (treatment) for the pavement. Pavement problems are generally determined by distress. "Bad Ride" is an obvious exception to this statement. A summary of specific pavement problems and their associated distresses are summarized in Table 4.

TABLE 4. Pavement Problem Summary

Pavement Problem	*Associated Specific Pavement Distresses*
Asphalt (AC)Pavements (inc. Flexible and rigid base and road mix)	
Flushing or Bleeding	Flushing
Non-Structural Cracking	Transverse, Longitudinal and Block Cracking
Insufficient Structure	Longitudinal Distortion, Rutting, Alligator Cracking
Unstable Base/Subbase	Alligator Cracking, Transverse and Longitudinal Distortion
Unstable Mix	Block Cracking, Rutting, Longitudinal Distortion
Aged Pavement	Rutting Transverse and Longitudinal Distortion, Alligator Cracking
Surface Raveling	Surface Raveling
Asphalt Overlay on Rigid Base	
Joint Deterioration	Transverse and Longitudinal Cracking
Unstable Mix	Rutting, Longitudinal Distortion
CRCP Distress	Patching
Rigid (PCC) Pavements	
Faulting	Faulting
Distressed Joints (except Type 6)	Longitudinal Joint Distress, Transverse Joint/Crack Distress

Slab Breakup	Slab Breakup
Pavement Deterioration	CRCP Deterioration
Patching	Patching
Surface Distress	Surface Distress
All Pavement Types	
Bad Ride	Roughness Measurements (IRI/PSI)
Rutting	Rut Depth

Examples of the pavement problem definitions are shown in Tables 5 and 6. For each problem, there is a brief discussion of the problem , the individual distresses (and associated distress levels) that make up the problem, and a listing of possible treatments and expected lives of those treatments.

Pavement Problem Level Evaluation

Determination of the severity or level of a pavement problem can be complex. Each problem is examined for every section of road. The first test is to compare the state of the road in question to the minimum distress levels for the problem being examined. If the minimum requirements are met an assessment of the problem level is made. Each problem has a criteria for determining the level based on a specific distress (or set of distress) levels. This can get to be a fairly intense effort when more than a couple of distress variables are interacting. Table 5 shows an example where three distresses are evaluated to determine the problem level.

TABLE 5. Example of Pavement Problem

INSUFFICIENT STRUCTURE

Problem Definition: For all pavement types (except AC over PCC), a pavement could have an insufficient Structure problem when one or more of the following exists:

- Longitudinal distortion greater than or equal to minor, *and/or*
- Rutting greater than minor, and/*or*

Code	Treatment	Life of Treatment
1	Spot Repair *	Remaining Life
4	Cold Recycle **	5 - 8 Years
5	Rut Fill	2 - 6 Years
7	Thin Overlay	4 - 8 Years
8	Thick Overlay	8 - 12 Years
9	Partial Mill & Overlay	10 - 12 Years
10	Full Depth Mill & Overlay	12 - 15 Years

11	Reconstruct	Full Life
12	Micro Surface	2-6 Years

¨ Alligator cracking greater than or equal to minor

Acceptable Treatments:

` * Only if less than 50' long
** Only on low emphasis routes, usually followed with a seal coat
*** Use multiple passes to "build up " surface

Pavement Problem Severity Matrices: The interrelationship between the various distress manifestations can result in a problem severity that is greater than any of the individual distress levels. The tables below summarize this relationship.

Alligator Cracking - None					Alligator Cracking - Minor			
Rutting Problem	Longitudinal Distortion Problem Level				Rutting Problem	Longitudinal Distortion Problem Level		
Level	None	Moderate	Severe		Level	None	Moderate	Severe
None	None	Moderate	Severe		None	None	Moderate	Severe
Minor	None	Moderate	Severe		Minor	Minor	Moderate	Severe
Moderate	Moderate	Severe	Severe		Moderate	Moderate	Severe	Severe
Severe	Severe	Severe	Severe		Severe	Severe	Severe	Severe
Alligator Cracking - Moderate					Alligator Cracking - Severe			
Rutting Problem	Longitudinal Distortion Problem Level				Rutting Problem	Longitudinal Distortion Problem Level		
Level	None	Moderate	Severe		Level	None	Moderate	Severe
None	Moderate	Severe	Severe		None	Severe	Severe	Severe
Minor	Moderate	Severe	Severe		Minor	Severe	Severe	Severe
Moderate	Severe	Severe	Severe		Moderate	Severe	Severe	Severe
Severe	Severe	Severe	Severe		Severe	Severe	Severe	Severe

Treatment Applications/Alternatives:

Pavement Problem severity	Minor(m)	Moderate(M)	Severe(S)
Treatment alternatives	1,4,5,7,12	5,7,8,10,11,12	8,10,11

TABLE 6. Example of PCC Pavement Problem

SLAB BREAKUP

Problem Definition:

For all jointed PCC pavements a pavement has a slab breakup problem when the slab breakup rating is equal to or greater than minor.

Acceptable Treatments:

Code	Treatment	Life of Treatment
2	Thin Overlay	2 - 4 Years
3	Full Depth Repair	5 - Remaining Life
6	Patch/Repair/Thin Overlay	6 - 10 Years
7	Patch/Repair/Thick Overlay	8 - 12 Years
8	Patch/Repair/Crack & Seat/Break & Seat/Thick Overlay *	12 - 15 Years
10	Rubblize & Thick Overlay	15-18 Years
11	Reconstruct	Full Life
13	Spot Patch/Repair **	Remaining Life

* Break & seat on jointed reinforced concrete pavement and crack & seat on jointed plain concrete pavement.

** On pavements with a short, joint spacing, this may include replacing the entire slab.

Pavement Problem Severity Matrix:

This problem is dependent only on the level of the severity for Slab Breakup. It should be noted that the problem severity is also dependent on pavement type.

Treatment Applications/Alternatives:

Pavement Problem Severity	Minor (m)	Moderate (M)	Severe (S)
Treatment Alternatives	13	2, 3, 6, 13	6, 7, 8, 10, 11

Treatment Alternatives

Once all of the pavement problems have been defined for a given pavement section, the next step is to evaluate these problems to determine the treatment alternatives. A palette of possible treatments are associated with each specific pavement problem. The acceptable treatment alternatives each have a numeric code. The treatment codes and associated costs are summarized in Table 7.

TABLE 7. Standard Pavement Costs for Pavement Rehabilitation

The following are estimates of the costs for various pavement treatments outlined in this study.

FLEXIBLE PAVEMENTS

		Cost (in $)			
PMS Code	Rehabilitation Technique	Low	High	Units	Notes
1	Spot Repair	variable	variable		
2	Seal Coat	6000	8000	Mile	2
3	Crack Filling	0.65	1.25	LF	
4	Cold Recycle - 3" - 5"	12000 15000	20000 25000	Mile Mile	2,3 2,3
5	Rut Fill	2000	12000	Mile	2
6	Surface Mill	3500	6500	Mile	2
7,8	Overlay	1.50	3.00	SY-IN	
9	Partial Mill	0.50	2.00	SY-IN	
10	Full Depth Mill	1.00	2.50	SY-IN	
11	Reconstruct	100000	200000	Mile	2,4
12	Micro Surface	18000	21000	Mile	

Notes:

1) highly variable, cost depends on problem
2) based on 2-12' lanes
3) range of costs dependent on the use of emulsions
4) based on pulverize and 4" overlay

RIGID PAVEMENTS

PMDSS		Cost (in $)			
Code	Rehabilitation Technique	Low	High	Units	Notes
2	Overlay	1.50	3.00	SY-IN	
3	Repair (10% max)	50	100	SY	
4	Repair and Grind	2.00	3.00	SY	
5	Repair, Grind and Thin Overlay	5.00	8.00	SY	

6	Spot Repair, Patch, Repair, Thin Overlay	2.00	7.00	SY	
7	Spot Repair, Patch, Repair, Thick Overlay	3.50	9.00	SY	
8	Repair, Patch, Crack/Seat, Thick Overlay	4.00	10.00	SY	
9	PCC Overlay	14.00	16.00	SY	
10	Rubbilize and Overlay	10.50	12.00	SY	3
11	Reconstruction	13.65	17.65	SY	4
12	Retrofit Dowels	25.00	35.00	Dowel	2
13	Spot Repair	variable	variable		1

Notes:

1) highly variable, cost depends on problem
2) Typical application calls for 6 dowels per lane per joint
3) assumes 5" overlay
4) assumes unbounded 10" overlay

A major effort in establishing the PPS was the determination of cost-effective, acceptable treatment alternatives that are appropriate for each pavement problem level. This is where a concentrated research effort, the use of updated PMS data, the incorporation of pavement performance models, and technology advancements in road building have greatly impacted our ability to develop the strategy presented here. The PPS matrices (examples shown in Tables 5 and 6) contain all the information required to guide a PPS user from pavement distresses to treatment alternatives.

Applicable Treatment Alternatives

This analysis is done by comparing each identified pavement problem (and its associated severity level) to the list of all possible treatments for that pavement type. Each treatment is classified as unacceptable (not appropriate for the problem), preferred (a treatment appropriate to the level of the problem), or excessive (a treatment which is more than necessary).

If all problems can be solved by a preferred treatment, that treatment alone constitutes the list of possible treatments. If no preferred treatments are acceptable for all the identified problems, the list is expanded to include excessive treatments. At least one treatment, reconstruction, will solve all problems so there will always be at least one treatment option.

Final Options

The final step in this process is to determine proper treatment options. Since there are typically constraints or extraordinary requirements that can effect treatment options, PPS identifies three levels of treatment. These levels include: "Low cost" (a budget constrained alternative), "Best Value" (the highest ratio of pavement life to cost), and "Longest Life" (an alternative for high functional class routes that cannot tolerate delays caused by extensive maintenance, rehab or reconstruction).

If there is more than one treatment in the list of possible treatments, the final step is to do some simple comparisons. Each treatment is associated with a cost and an expected life. The "Lowest Cost" solution is the one with lowest associated cost. The "Best Value" solution is associated with the highest ratio of expected life to cost. The "Longest Life" treatment is the one associated with the longest expected life.

A sample of this analysis is shown in Table 8. In this case, the analysis was done on a section of road for it's condition in 1997 (a) and 2003 (b). In this case, using the "best value" alternative, if action is taken now, simple crack filling (c) will be sufficient for most of the pavement. However, if nothing is done for 5 years, the pavement will require substantial work, rubbilize and overlay in this case (d).

Table 8. Standard Report from Wisconsin's PMS

Highway Performance Projection Summary

From Location: STH 186N INT R

Total Length: 8.36 miles in 8 PIF sections

Pavement Type: 8.36 miles of Asphalt over Concrete

			(a)1997			(b)2003	
Index Summary	Miles	Avg.	Min.	Max.	Avg.	Min.	Max.
PDI:	8.36	37.05	36.00	44.00	61.05	60.00	68
PSI:	8.36	2.39	2.21	2.80	1.67	1.49	2.08
IRI:	8.36	140.92	122.00	150.00	170.92	152.00	180
		Low	Best	Long	Low	Best	Long
Treatment Options (miles)							
		Cost	Value	Life	Cost	Value	Life
0-Do Nothing		0.00	0.00	0.00	0.00	0.00	0.00
1-Spot Repair		0.00	0.00	0.00	0.00	0.00	0.00
2-Seal Coat		0.00	0.00	0.00	0.00	0.00	0.00
3-Crack Fill		7.26	(c) 7.26	0.00	0.00	0.00	0.00
4-Cold Recycle		0.00	0.00	0.00	0.00	0.00	0.00
5-Rut Fill		0.00	0.00	0.00	0.00	0.00	0.00
6-Surface Mill		0.00	0.00	0.00	0.00	0.00	0.00
7-Thin Overlay		0.00	0.00	7.26	0.00	0.00	0.00
8-Thick Overlay		0.00	0.00	0.00	0.00	0.00	0.00
9-Partial Mill and Overlay		0.00	0.00	0.00	0.00	0.00	0.00
10-Full Depth Mill and Overlay		0.00	0.00	0.00	0.00	0.00	0.00
11-Reconstruction - AC		1.10	1.10	1.10	1.10	1.10	1.10
12-Micro Surface		0.00	0.00	0.00	0.00	0.00	0.00
13-Thin Overaly over PCC		0.00	0.00	0.00	0.00	0.00	0.00
14-Repair		0.00	0.00	0.00	0.00	0.00	0.00
15-Repair and Grind		0.00	0.00	0.00	0.00	0.00	0.00
16-Repair, Grind and Thin Overlay		0.00	0.00	0.00	0.00	0.00	0.00
17-Patch, Repair and Thin Overlay		0.00	0.00	0.00	7.26	0.00	0.00
18-Patch, Repair and Thick Overlay		0.00	0.00	0.00	0.00	0.00	0.00
19-Crack/Seat and Thick Overlay		0.00	0.00	0.00	0.00	0.00	0.00
20-PCC Overlay		0.00	0.00	0.00	0.00	0.00	0.00

21-Rubbilize and Overlay	0.00	0.00	0.00	0.00	(d) 7.26	0.00
22-Reconstruction - PCC	0.00	0.00	0.00	0.00	0.00	7.26
23-Retrofit Dowels	0.00	0.00	0.00	0.00	0.00	0.00
24-Spot Repair	0.00	0.00	0.00	0.00	0.00	0.00

Other Considerations

The level of complexity in this process is quite obvious. It would be difficult if not impossible to execute this level of evaluation on any large sample of state highways without some sort of automated support. In this case, all of the elements discussed have been incorporated into a new and revitalized Pavement Management System for evaluating pavement performance and the new "Meta-Manager" system developed for evaluating all programming options including bridges, capacity expansion, safety, etc.

The "Meta-Manager" evaluates threshold information for programming considerations. PMS evaluates all pavement sections to determine (based on PIF segmentation) whether a threshold has been reached or not. It can also be used to report index (PSI, PDI, IRI, Rutting) values. Wisconsin's PMS has been set up such that the user can select any project limits and have that project (one or more PIF sections) evaluated using the process outlined above. Table 8 shows a sample output from this process. It should be noted that there are several different standard reports provided. This is simply one of the more comprehensive and interesting of those reports.

CONCLUSION

The pavement evaluation process presented here provides a logical approach to progressing from field observations of distress to proposed treatment strategy.

Measurements of ride, rut and distress (PDI) are compared to thresholds established for each of these measurements.

When one or more thresholds for a pavement section are crossed, the need for treatment is established.

Specific pavement distresses are used to define specific pavement problems.

Field measurements (observations) of the severity and extent of specific pavement distresses are used to define pavement distress levels.

Matrices of pavement distress levels are used to define pavement problem levels.

Each identified pavement problem (and its associated problem level) is compared to the list of all possible treatments for that pavement type.

Each treatment is classified as unacceptable (not appropriate for the problem), preferred (a treatment appropriate to the level of the problem), or excessive (a treatment which is more than necessary).

Finally, treatment levels identified as "Low Cost", "Best Value", and "Longest Life" are established based on manipulation of cost and expected life data for each treatment on the short list of viable options.

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